Climate change – aridification – changing soil – transforming landscape

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1. Abstract

Through the change of the natural water cycle climate change results in significant landscape changes. Processes are primarily induced by the permanent shortage in groundwater, which can lead to the transformation of soils and as a consequence to the modification of vegetation. During several decades of research on the lowland territories of Hungary we determined the degree of water shortage in soils. It was also proved that changes, especially in terms of saline areas, resulted in significant transformations (e.g. decrease of salt content, significant drop of Na, increase of humus content). These processes affect not only natural landscapes, but also have serious economic consequences.

2. Introduction

Recently the amount of available data proving the consequences of global climate change has increased intensively. The most extensive review of these proofs is published in the 2007 IPCC report (Metz, B. 2007). The most frequently cited proofs are climatic data, which have a great fluctuation among natural conditions anyway. A good example is the highly variable annual mean precipitation of Hungary *(Fig. 1)*, which was 515, 780 and 400 mm concerning the three years between 1998 and 2000. What is more, if smaller territories are considered much greater extremities can be experienced. Consequently, it is not by chance that time to time the role of global climate change is underestimated and climatic fluctuations are viewed as natural variations. Therefore those *longer term changes should also be investigated and preferably quantified* which show little variation but sign unidirectional trends. Based on our research of the past 30 years, a marker of this type can be the system of groundwater, soil and natural vegetation.

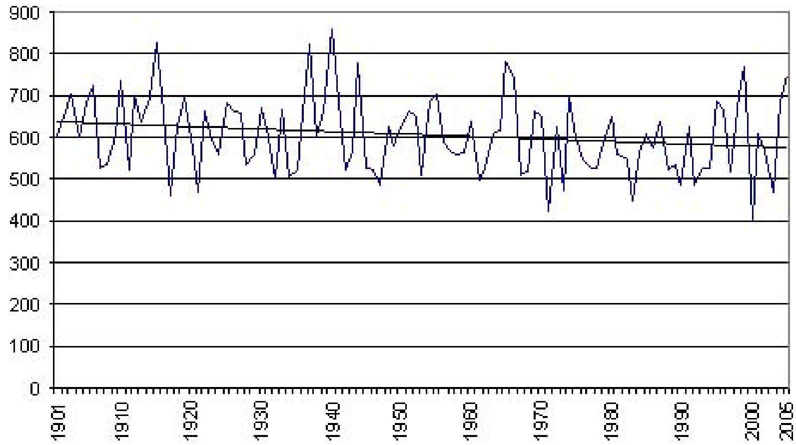


Figure 1 Annual mean precipitation in Hungary (mm) and the trend of its change (1901-2005)

3. Consequences of changes in the water cycle

The key factor behind environmental change is usually the alteration of the water cycle, which influences the character of landscape components through direct and indirect processes, amplified frequently by additional anthropogenic impacts. (The sketch of relevant mechanisms are presented in Fig. 2.)

Climate change induces both short term and long term alterations in the water cycle. Short term changes, signed by droughts, crop failures, flood events etc., can be observed fairly unambiguously. Concerning long term changes, the perception of which is not at all straightforward, one of the most important is groundwater depletion, which can exert its effects through various interrelated mechanisms.

Firstly, the deeper the water table moves the more difficult the plants can reach and utilise groundwater, which finally leads to the decrease of the biomass (Kovács, F. 2005). In extreme cases, groundwater depletion might cause permanent changes in the composition of natural vegetation, or in case of agricultural areas the selection of grown crops. Secondly, changes in groundwater can also modify the vertical water and salt transfer in soils, which might result in the transformation of genetic soil types. As a consequence, sodification processes or under reverse conditions desalination can be observed. In both cases the modification of soil type is followed by the change of natural vegetation.

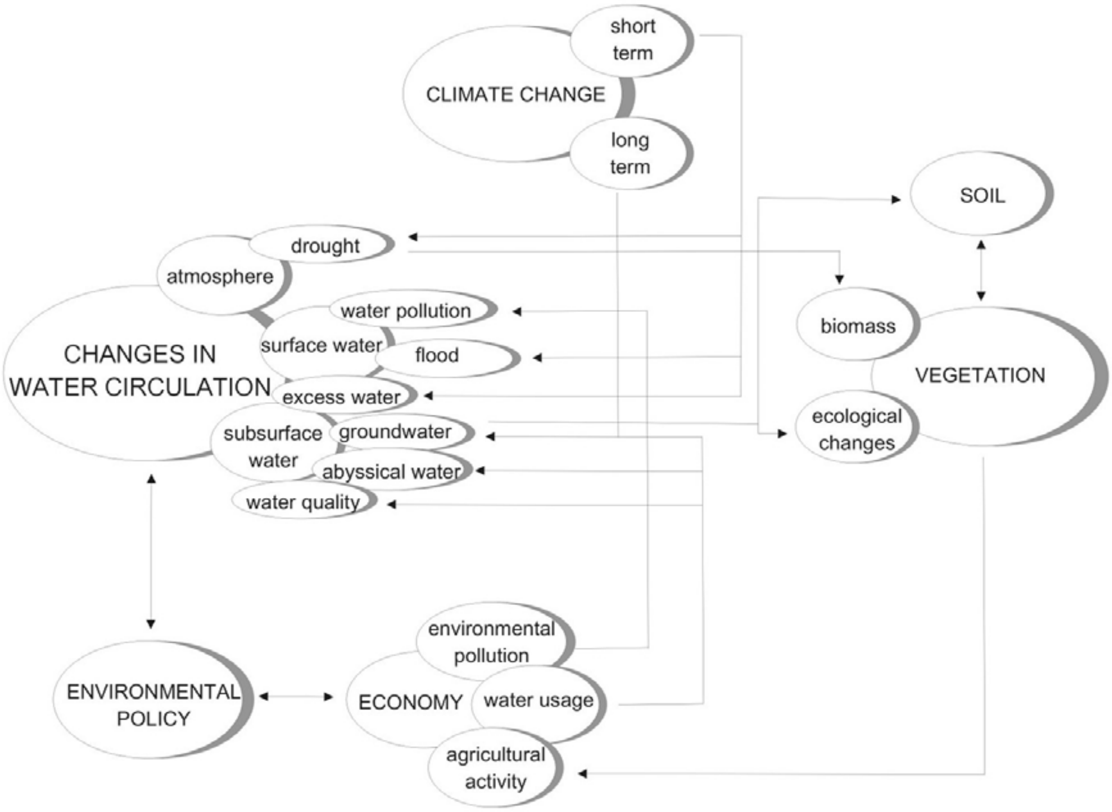


Figure 2 Environmental consequences of changes in the water cycle

4. The degree of groundwater shortage

As a result of precipitation decrease, especially from the 1980s, the greatest changes in the groundwater table, which sank at some locations by 7 m, were experienced on the Danube-Tisza Interfluve. (Note however that at some locations in the Nagykunság and Jászság, being intensively irrigated, a slight groundwater rise was detected.)

It is novel even in an international comparison that we applied remote sensing and GIS for *determining the degree of annual water shortage, being 4.8 km^3 in 1995 and 2003* (Table 1). The above value is seemingly low, however it is almost as much as the *total annual water consumption of Hungary* (Rakonczai 2002, Rakonczai-Kovács 2006).

Beside climatic reasons there are further reasons for groundwater depletion on the Danube-Tisza Interfluve. However, the dominant role of precipitation shortage seems inevitable, as due to the geomorphology of the territory the *only source of groundwater is rainfall* (except areas along the two rivers).

Table 1 Estimated water shortage on the Danube-Tisza Interfluve compared to data of the early 1970s

Year	Water deficit (km^3)
1980	1,15
1985	2,32
1990	4,08
1995	4.80
2000	2,84
2003	4,81

5. Transformation of soils

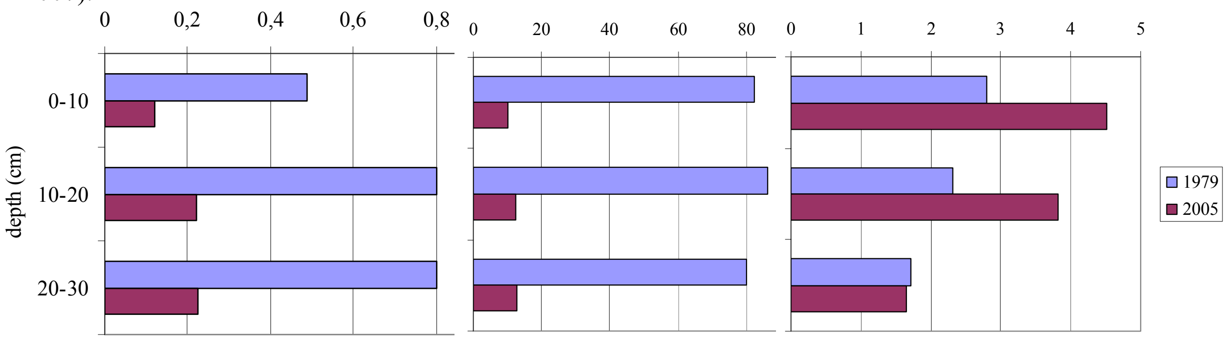
Permanent groundwater shortage may induce significant changes in soils according to our experiences and measurements at various locations on the plain territories of Hungary.

In the middle of the 1970s detailed geomorphological and pedological investigations were made on the Szabadkígyós Steppe (being a unit of the Körös-Maros National Park at present) as a part of the preparations for declaring the area protected. Beside the precise morphological mapping of sodified bench microforms, sample plots were identified for joint evaluations made together with botanists. In the framework of the later study detailed botanic surveys were made along with the analysis of the chemical parameters of soils lying under different vegetation types. At that time nobody thought that after 25-30 years transformations could be detected on the anyway static landscape.

The research activity has been renewed at Szabadkígyós from 2003, when it was noticed on a field trip that during the elapsed quarter of a century the previously saline territory significantly changed, though most of the original sampling sites remained identifiable. We have already suspected at this point that the observed transformations were driven by the changes in the water cycle. Later it turned out that there were some further factors in the background as well, though the aridity experienced between the late 1980s and mid 1990s seemed to be the most important factor behind changes. During the long lasting drought period the groundwater table sank, and thus the effect of waters, having sometimes a 5000 mg/l salt content, became less and less apparent on the surface. As a result saline precipitations started to disappear from the soil surface (Fig. 3), and the decreasing salt content enabled the gradual advance of grassy vegetation (Fig. 4).


Figures 3-4 Disappearing saline landscape and the advance of vegetation between 1976 and 2006

Samples collected in 2005 made the quantitative assessment of soil transformation possible. Results justify the physical and chemical background of landscape modification. During the past 30 years due to the mentioned environmental changes the total salt content of soils has decreased significantly, especially the amount of Na dropped (Figs. 5 and 6), thus providing more favourable conditions for plants. The gradual advance of vegetation has been followed by the considerable increase of humus content (Fig. 7) (Barna, Gy. 2007).



Figures 5-7 The change of total salt (S%) sodium (% of cations) and humus content (%) between 1979 and 2005 in one of the profiles

The one and a half decade long drought period has strengthened the areal type of bench erosion. This is also proved by the fact that numerous bench microforms mapped in the late 1970s has disappeared by now, however their place is clearly signed by patches of vegetation requiring different salt content than their environment (Figs. 8-9). This pattern, identical to that of the original benches could have not developed if forms had been eroded from their rims in the classical way.


Figures 8-9 The permanent dry period increased the role of areal bench erosion

6. Conclusions

Our research, applying various methods, has proved that the outcomes of global climate change can be assessed not only by climatic data. The modification of water reserves and especially the transformation of soils do not resemble the episodic extremities but rather sign the trend of changes.

There are various important consequences of the above processes. The fertility of soils can change (in the above mentioned case it improves) and in the meantime characteristic landscape elements under natural protection may disappear due to climatic causes (e.g. the special Hungarian "puszta" is transforming at many locations). As a matter of vegetation change on saline landscapes some very valuable medicinal herbs such as the chamomile are also in repression. As a consequence the amount of harvest has decreased, leading to the back drop of Hungarian medicinal herb export.

Although there have been detailed scientific evaluations published on the consequences of climate change in Hungary (Láng et al. 2007) in practice we have experienced that environmental politics hardly considers these, especially if a research, such as ours, focuses on slower, low magnitude changes. Attention is mostly paid to climatic extremities and their spectacular consequences (storms, floods), albeit these are mostly representing natural variations.

Beside their effects on the landscape the decrease of groundwater reserves, the transformation of soils and the slow modification of vegetation can have significant economic consequences as well, thus these processes should deserve an increased attention.

7. References

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